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Original article

Outcomes and prognostic factors in revision hip arthroplasty for severe intra-pelvic cup protrusion: 246 cases

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ABSTRACT

Background: The outcome of revision total hip arthroplasty (THA) for intra-pelvic cup protrusion is unclear. Hence, we conducted a large retrospective study to clarify the surgical strategy (hip lever arm and cup mechanical fixation) and the outcomes of reconstruction for severe intra-pelvic cup protrusion.
Hypothesis: We hypothesized that restoration of the anatomic hip centre in such acetabular revisions decreased the risk of recurrent loosening.
Material and methods: The study included 246 THA procedures (in 220 patients), with a follow-up of 5.2 ± 4.9 years (1–24.2) after the index surgery. Bone loss was estimated using the SOFCOT classification (grade III or IV in 80% of cases) and the Paprosky classification (IIIA or IIIB in 58% of cases). Quality of the reconstruction was assessed on X-rays according to the correction of the protrusion and position of the hip centre of rotation.
Results: After a clinical follow-up of at least 5 years, with a mean of 9.9 ± 4.1 years (5–24 years), the mean Postel-Merle d'Aubigné score was 14.2 ± 3.1 and the mean Harris Hip Score was 78.0 ± 18.7. Cup protrusion was partially or completely corrected in every case and cup position was normal in 27 (11%) cases. The centre of rotation was within 10 mm of the physiological position in 158 (64.2%) cases, acceptable in 77 (31.3%) cases, ascended in 9 (3.7%) cases, and worsened in 1 (0.4%) case. Revision for cup or cup and femoral failures was required in 24 (9.8%) cases. Cumulative survival rates with cup loosening as the endpoint were 88.5% after 5 years, 79.9% after 10 years, and 63.9% at last follow-up at 13.6 years.
Discussion: Our hypothesis that restoration of anatomic hip centre decreased the risk of recurrent loosening was not verified: success or failure in restoring the normal centre of rotation did not correlate significantly with final cup status. Recurrent aseptic loosening was the cause of failure in 9.8% of cases. Ensuring long-term effective mechanical stability had a greater impact on global outcomes than restoring an ideal centre of rotation.
Level of evidence: IV, retrospective study.

1. Introduction

Among reasons for revision of total hip arthroplasty (THA), severe intra-pelvic cup protrusion requiring cup revision raises multiple challenges. In particular, the intra-pelvic vessels and nerves are at risk for injury [1] and difficulties with bone reconstruction may require massive acetabular allografts [2]. Few studies have specifically addressed this issue, despite the availability of multiple anecdotal case-reports (61 articles about 1 to 4 patients published between 1990 and 2012 [1,3]). No specific classification has been developed, although the latest classification by Paprosky et al. distinguishes a Type 3B characterized by supero-medial (up

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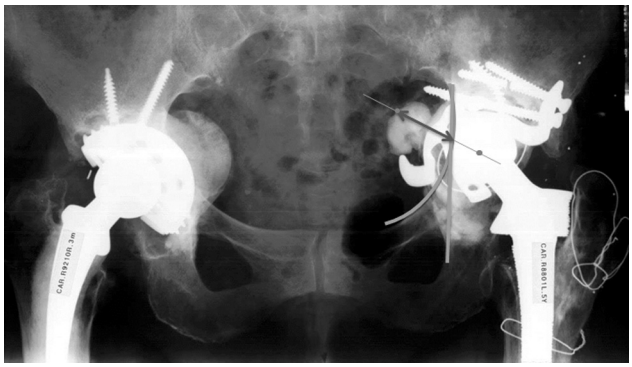

Fig. 1. Severe intra-pelvic protrusion was defined as a distance of at least 15 mm between any of the prosthetic components and the ilio-ischial line.

and in) cup protrusion [3]. The only therapeutic recommendations are those developed by Girard et al. [4].

We therefore conducted a large retrospective study with the following objectives:

- to assess the influence of reconstruction quality on arthroplasty outcomes and survival;
- to determine the failure rate of acetabular reconstruction (with or without cement) and causes of failure;
- to evaluate whether an accurate evaluation of the lesions limited the risk of intra-operative complications and improved selection of the surgical approach;
- to determine the rates of intra-operative and postoperative complications.

We hypothesized that restoration of the anatomic hip centre decreased the risk of recurrent loosening.

2. Material and methods

2.1. Patients

A multicentre study (17 institutions) was used to recruit 246 hips in 220 patients. Overall, time since index surgery was 5.2 ± 4.9 years (1–24.2); follow-up was at least 2 years in 134 (64.4%) cases, more than 5 years in 99 (39.8%) cases, and more than 10 years in 26 (16.8%) cases (Table 1). Mean age at cup revision was 66 ± 14.7 years (21–90) and 73% of patients were women. Time since failed THA with protrusion was longer than 10 years on average, longer than 15 years in 17% of cases, and longer than 20 years in 15% of cases. A previous history of repeat cup revision was noted for 123 (50%) hips, including 30 (12%) with three or more previous revisions. Aseptic loosening was the rule (228 [93%] hips). Septic loosening was confirmed in 12 (5%) cases, whereas in 5 (2%) cases there was some doubt about the presence of infection. The revision was usually confined to the acetabulum (226 [92%] cases), while 158 (66%) cups were cemented initially (Table 1).

Inclusion criteria were defined based on the extent of intra-pelvic cup protrusion. In patients with cup loosening, intra-pelvic protrusion of any prosthesis-related component, whether metallic or non-metallic, was considered "severe" if the component was located at least 15 mm medial to the ilio-ischial (Köhler's) line (Fig. 1).

2.2. Evaluation and intra-operative data

Preoperatively, in addition to standard radiographs, other imaging studies were performed in 154 (58%) cases, although vascular imaging was performed in only 42 (17%) cases (Table 2).

Table 1
Demographic data and preoperative status.

Demographic data	Number of hips/patients 246/220		Range
Period from cup insertion to revision for protrusion			
Overall	246	5.2 ± 4.9 years	1–24.2 years
5–9 years	56	23.1%	
10–14 years	33	13.6%	
15–19 years	8	3.3%	
>20 years	2	0.8%	
Mean age (years) at revision	246	66 ± 14.7 years	21–90 years
Sex			
Females	160	72.7%	
Males	60	27.3%	
ASA score			
I	28	12.6%	
II	151	68.9%	
III	41	18.5%	
IV or V	0	0	
Number of previous cup arthroplasties			
Mean	246	1.64 ± 0.76	1 to 5
1	123	50.2%	
2	93	37.6%	
3	25	10.2%	
4	4	1.6%	
5	1	0.4%	
Time since last cup arthroplasty			
Mean	246	11.1 ± 7.6 years	0.1–40 years
0–4 years	58	23.7%	
5–9 years	53	21.2%	
10–14 years	56	22.8%	
15–19 years	42	17.0%	
>20 years	37	15.3%	
Type of revision			
Aseptic	228	93.1%	
Septic	12	4.9%	
Doubtful	5	2.0%	
Type of revision			
Cup only	226	91.9%	
Bipolar	20	8.1%	
Initial cup interface			
Cemented	158	64.2%	
Cementless	88	35.8%	

A specific sub-peritoneal approach was used in only 14 (5%) cases and a trans-femoral approach to facilitate acetabular exposure in 13 (5%) cases. Only 13 (5%) cases were managed using a two-stage procedure (because of infection and/or reconstruction difficulties in the event of a vascular approach).

Bone loss was estimated using the SOFCOT classification [5] for 240 hips, of which 191 (80%) were grade III or IV; and using Paprosky's classification [3] for 182 hips, of which 100 (58%) were grade 3A or 3B (Table 2). Bone defect reconstruction was performed for 226 (91%) hips (167 allografts, 35 autografts, and 24 substitutes). A metallic reconstruction device was implanted in 154 (62%) cases (including 51 Bürch-Schneider cages in 51 and 46 with a Kerboull cross-plates) (Table 2). Only 62 (25%) cups were cementless. Mean cup size was 54 mm and only 35 (14%) jumbo cups (>58 mm) were used. Dual-mobility cups were implanted in 58 (24%) cases and a fixed insert in 188 cases (Table 2).

2.3. Assessment of outcomes

The data were collected in electronic case-report forms using the OrthoWave™ Software Suite (ARIA, Bruay-Labuissière, France) [6] to enter the clinical and radiographic information related to the revision procedure and to perform the statistical analysis. The

Table 2
Preoperative evaluation and surgical data.

	n	%
Preoperative evaluation		
Additional imaging studies		
Arteriography	12	4.9
Preoperative CT	102	41.5
CT-angiography	30	12.4
Bone loss		
SOFCOT classification *n* = 240		
Stage 0	1	0.4
Stage 1	2	0.8
Stage 2	46	19.2
Stage 3	117	48.8
Stage 4	74	30.8
Paprosky's classification *n* = 182		
Paprosky Ac 1	1	0.55
Paprosky Ac 2a	4	2.2
Paprosky Ac 2b	6	3.3
Paprosky Ac 2c	71	39.01
Paprosky Ac 3a	20	10.99
Paprosky Ac 3b	80	43.96
Operative data		
Approaches		
Postero-lateral	118	48.16
Anterior	93	37.96
Lateral	9	3.67
Trans-trochanteric	3	1.22
Other	1	0.41
Antero-lateral	6	2.45
Hardinge	15	6.12
Additional approach		
None	212	89.0
Sub-peritoneal iliac	13	5.3
Trans-femoral	13	5.3
Double articular approach	1	0.4
Number of revision stages		
1 stage	233	94.7
2 stages (without a spacer)	10	4.1
2 stages (with a spacer)	3	1.2
Bone reconstruction		
None	20	8.1
Allograft	167	67.9
Autograft	35	14.2
Bone substitute	24	9.8
New cup fixation		
Cemented	184	75
Cementless	62	25
Additional fixation		
None	47	19.1
AMU ring	48	19.5
Bürch-Schneider cage	51	20.7
Kerboull cross-plate	46	18.7
Morcelised allograft	45	18.3
Simple grid	9	3.7
Cup size (mm)		
Mean: 53.5 (44–64)		
<48	17	7.1
50–56	194	78.8
>58	35	14.2
Type of insert		
Fixed insert	188	76.4
Dual-mobility	58	23.6

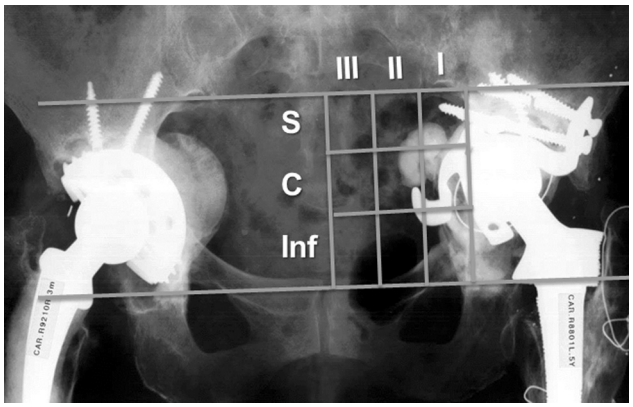

Fig. 2. Nine rectangles were defined, according to the original SFHG classification, by two horizontal lines connecting the teardrops and the distal ends of the sacro-iliac joints and by two perpendicular lines, the midline and the ilio-ischial line. In the distal to proximal direction, the three horizontal levels were labelled superior (S), central (C), and inferior (Inf) for each of the three lateral-to-medial levels (I, II, and III).

clinical evaluation was based on the Postel-Merle d'Aubigné (PMA) score [7] and the Hip Harris Score [8].

The hips were divided into four categories depending on whether the protrusion was global or involved only the cup, only the cement, or only metallic material. In each category, the extent of protrusion was determined using the mapping system developed by the French Society for Hip and Knee Surgery (*Société Française de chirurgie de la Hanche et du Genou* [SFHG]). This system distinguishes nine zones defined by two horizontal lines, connecting the distal ends of the sacro-iliac joints superiorly and the teardrops inferiorly, and by two vertical lines, the ilio-ischial line laterally and the sacrum-pubis axis medially (Fig. 2). Protrusion to the lateral column was defined as type I, to the medial column as type II, and to the central column as type III.

The quality of the reconstruction was evaluated radiologically based on correction of cup protrusion and on the position of the prosthetic centre of rotation. The centre of rotation was defined as restored if it was between 0 and 10 mm from the physiological position, acceptable if it was between 10 and 25 mm, improved if it was greater than 25 mm, and worsened if it was less favourable than the preoperative position.

2.4. Statistical methods

Statistical correlations were evaluated using multivariate analyses, the non-parametric Kruskal-Wallis test, Student's *t*-test, and Pearson's Chi^2 test. Survival was evaluated using the Kaplan-Meier method using isolated cup or bipolar (cup and femur) revision for any reason or aseptic loosening as the endpoint, comparison by the log-rank test, and at least 30 available cases in the last interval. Values of $P < 0.05$ were considered significant.

3. Results

3.1. Clinical outcomes

After a clinical follow-up of at least 5 years and a mean follow-up of 9.9 ± 4.1 years (5–24 years) for 116 evaluated hips, the mean PMA score improved from 8.7 ± 2.4 (3 to 14; maximum possible score, 18) preoperatively to 14.2 ± 3.1 (5 to 18) at latest follow-up. So-called "forgotten hip" status (PMA score of 18 points) was achieved in 17% of cases. The mean HHS improved from 42.2 ± 16.4 (3 to 85; maximum possible score, 100) to 78.0 ± 18.7 (22 to 100) (Table 3).

Table 3
Postel-Merle d'Aubigné score (PMA) and Harris Hip Score (HHS) before revision and after at least 5 years of follow-up ($n = 116$).

$n = 116$	Preoperatively	After ≥5 years	P value (Student's t-test)
PMA pain/6	2.4 ± 1 (0–6)	4.9 ± 1.17 (1–6)	0.73
PMA mobility/6	4.2 ± 0.9 (2–6)	5.1 ± 1.06 (1–6)	**< 0.001**
PMA walking/6	2.0 ± 0.9 (0–5)	4.1 ± 1.53 (0–6)	**0.006**
PMA total/18	8.7 ± 2.3 (3–14)	14.2 ± 3.07 (5–18)	0.065
HHS pain/44	16.2 ± 8.9 (0–44)	37.1 ± 9.57 (0–44)	0.28
HHS function/47	19.3 ± 8 (0–41)	33.7 ±10.94 (3–47)	**0.0018**
HHS total/100	42.15 ± 16.4 (3–85)	78 ± 18.7 (22–100)	0.26

Bold characters indicate significant difference.

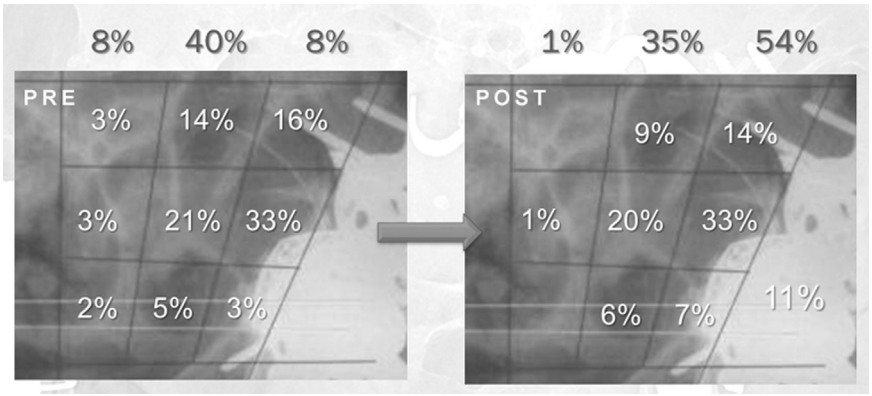

Fig. 3. Distribution of the cups in the nine protrusion zones before and after revision surgery.

In over half the cases, significant correction of the protrusion was achieved. Correction was complete in 27 (11%) cases. The number of type III protrusions decreased from 20 (8%) preoperatively to 2 (0.8%) after revision (Fig. 3). The centre of rotation was restored in 158 (64.2%) cases, acceptable in 77 (31.3%) cases, ascended in 9 (3.7%) cases, and worsened in 1 (0.4%) case; in the remaining case (0.4%), head and neck resection had been performed.

Table 4 reports the correlations linking the clinical outcomes to the status of the centre of rotation (i.e., restored or not) after at least 5 years; the case with head and neck resection was not included in the estimate of the centre of rotation. No significant correlation was found between the centre of rotation and pain intensity or total HHS. However, a greater degree of restoration of the centre of rotation correlated with better function according to HHS score. The degree of correction of the centre of rotation was not influenced by whether the initial cup was cemented or not (Table 5).

3.2. Complications and re-operations

Table 6 details the 73 (29.7%) complications recorded in the 246 cases. There were 21 dislocations (including 14 with an early onset), including 8 that required revision surgery for recurrent instability. All 19 cases of infection occurred within 4 years (mean, 1.2 years) and 10 of them required prosthetic revision. The 4 vascular complications consisted of 2 cases of ischemia, 1 of hematoma, and 1 of venous compression; these vascular complications were rare but serious, with 2 of them causing early death. No specific preoperative features associated with subsequent vascular complications were identified. All 5 cases of sciatic nerve (all recorded in the fibular nerve area) involvement had a spontaneously favourable outcome.

In addition to the 8 revisions for infection (2 with and 6 without a previous history of infection) and 8 revisions for instability, 24 (9.8%) revisions were required for failure of the cup or of both components due to aseptic loosening. The time to recurrent loosening was fairly short: within the first 2 years in 12 (50%) cases, within the first 5 years in 17 (71%) cases, and within the first 10 years in 23 (96%) cases. As shown in Table 7, the rate of failure due to loosening of the cup or of both components correlated with several variables (restoration or non-restoration of the centre of rotation, fixed or mobile insert, and initial degree of bone loss), but none of these correlations was statistically significant.

3.3. Cumulative survival rates

The cumulative survival rate to revision for aseptic cup loosening estimated using the Kaplan-Meier method was 88.5% (0.83–0.93) after 5 years, 79.9% (0.73–0.87) after 10 years, and 63.9% (0.50–0.82) at last follow-up after 13.6 years (Fig. 4) with 30 hips remaining for assessment in the last interval. Restoration of the centre of rotation had no significant influence on 13-year survival (69.9% with vs. 63.6% without restoration, $P = 0.795$, log-rank test). In contrast, the fixation method influenced survival,

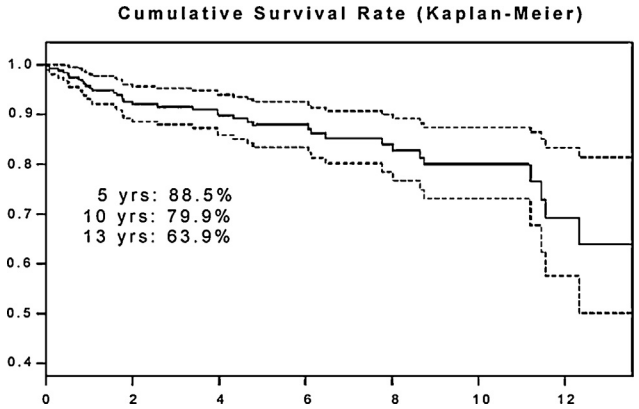

Fig. 4. Kaplan-Meier plot of the cumulative survival rate (in years) in the overall case-series, with revision for isolated cup or femur revision and cup revision for aseptic loosening as the endpoints. After 13.6 years, cumulative survival was 63.9% (0.50–0.81).

Table 4
Correlations linking pain, function, and total Harris Hip Score values to restoration of the centre of rotation of the hip.

Centre of rotation	Pain/44		Function/47		Total/100	
1 – Restored	37.9 (10–44)	ANOVA: $P = 0.844$	33.7 (3–47)	**ANOVA: $P = 0.0268$**	78.9 (22–100)	ANOVA: $P = 0.125$
2 – Acceptable	36.9 (0–44)	KW: $P = 0.671$	32,3 (5–47)	KW: $P = 0.352$	76.3 (22–100)	KW: $P = 0.422$
3 – Ascended	37.1 (20–44)		31.0 (9–47)		77.1 (46–100)	

Bold characters indicate significant difference. ANOVA: analysis of variance; KW: Kruskal-Wallis test.

Table 5
Influence of fixation method on restoration of the centre of rotation of the hip.

Centre of rotation	Cementless	%	Cemented	%	
1 – Restored	37	59.3	121	65.9	Chi^2: $P = 0.204$
2 – Acceptable	22	35.6	55	30.1	
3 – Ascended	3	5.1	6	3.4	
4 – Worsened	0	0	1	0.6	

Table 6
Failure with re-revision according to various factors (data for cross-tabulation available for 26 failed and 220 successful cup revisions for severe intra-pelvic protrusion).

Predictor	Failure	%	Success	%	*P* value
Centre of rotation					
Restored	15	57.7	136	64.8	0.675
Acceptable	9	34.6	66	31.4	
Ascended	2	7.7	7	3.3	
Worsened	0	0.0	1	0.5	
Type of prosthesis					
Conventional (fixed insert)	23	88.5	157	74.8	0.121
Dual-mobility	3	11.5	53	25.2	
Preoperative bone loss					
Paprosky 1–2a	0	0	13	6.2	0.140
Paprosky 2b	8	30.8	81	38.6	
Paprosky 3a	11	42.3	90	42.9	
Paprosky 3c	7	26.9	26	12.4	

Table 7
Complications and failures after cup revision for severe intra-pelvic protrusion.

Type	Cause		*n*	
Complications ($n = 73$ [29.7%])	Dislocation	Early	14 (5.7%)	Including 8 re-revisions (3.3%)
	$n = 21$ (8.5%)	Delayed	7 (2.8%)	
	Infection	Recovery	10 (4.1%)	Mean time to onset 1.2 years
	$n = 19$ (7.7%)	Revision	8 (3.3%)	(0–4 years)
		Death	1 (0.4%)	
	Vascular	Low. Lb. ischaemia	2 (0.8%)	Severe: 2 deaths
	$n = 4$ (1.6%)	Intra-pelvic haematoma	1 (0.4%)	Early
		Venous compression	1 (0.4%)	No preoperative risk factors
	Neurological: sciatic nerve	Paprosky 2a	1/4	Resolved spontaneously in all
	compression	Paprosky 2c	2/71	cases
	$n = 5$ (1.96%)	Paprosky 3b	2/80	More common with major
	Implant rupture	1 Kerboull cross-plate (after 3		bone loss ($P < 0.0001$)
	$n = 5$ (1.96%)	years); 1 Octopus (after 1 year);		
		3 Bürch-Schneider cages (after		
		6 months, 6 years, and 7 years)		
		4 with loosening and cup		
		revision		
Cup revision ($n = 40$–16.3%)	Reasons other than aseptic	Instability	8 (3.2%)	Revision with dual-mobility
	loosening			cup
		Infection	8 (3.2%)	Including 2 with previous
				infection
	Aseptic loosening	Cup	24 (9.8%)	Including 17 (62%) within 5
				years

which was significantly lower for cementless cups than with cups cemented in a reinforcement ring (70% [0.50–0.90] vs. 89% [0.82–0.94] after 4.7 years, respectively; $P = 0.026$, log-rank test).

4. Discussion

The study results do not support our hypothesis that restoration of the anatomic hip centre decreases the rate of recurrent loosening. In addition, anatomic hip recentring correlated neither with pain intensity nor with the total HHS, although optimal restoration of the centre of rotation correlated with better hip function (HHS score). Finally, restoration of the centre of rotation did not significantly influence prosthesis survival after the longest follow-up of 13 years. When planning the surgical strategy for revision surgery performed because of severe cup protrusion, if a choice must be made, then preference should be given to ensuring long-term stability rather than to trying to restore the ideal centre of rotation [9].

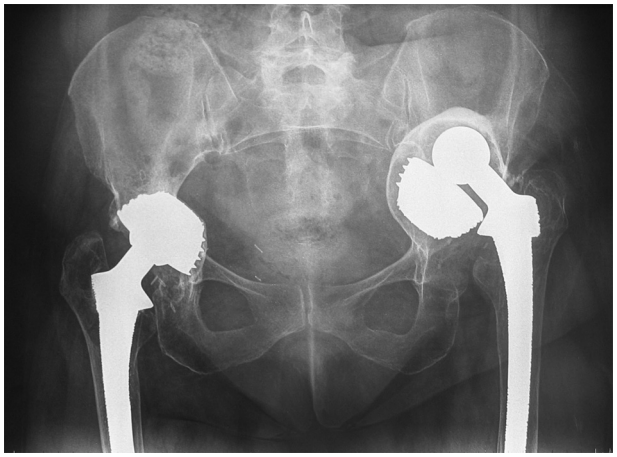

Fig. 5. When the migrated cup is surrounded by a protective bony shell (left hip), vascular imaging is unnecessary.

Although we had a very large cohort of cup revisions for severe intra-pelvic protrusion, our study exhibits the limitations inherent in retrospective series. In particular, the reconstruction methods used were diverse, the lesions and clinical status of the patients varied widely, and no published classification is available to date for describing severe intra-pelvic cup protrusion. On the other hand, the very long follow-up strengthens the reliability of the conclusions, particularly regarding the survival curves, which were analysed with at least 30 hips under study during the last interval. In addition, the clinical outcomes were assessed using validated scoring systems applied after a follow-up of at least 5 years. The strongest point of the study is the large number of hips and the multicentre recruitment to counteract the fairly low occurrence of severe intra-pelvic cup protrusion. Thus, this SFHG case-series is the largest published to date. In a study of largely similar lesions, Christie et al. [10] included only 78 cases.

The most common reason of cup revision failure was aseptic loosening (24/246, 9.8%). The short time to aseptic loosening confirms the importance of scrupulously following basic rules, including the immediate achievement, during the procedure, of reliable mechanical support and effective biological filling of bone defects [11–17]. Thus, 62% of the failures occurred within 5 years of the revision procedure and reflected either inadequate surgical technique or device failure, with better survivals in the subgroups managed with cementing in a reinforcement ring. Regarding the selection of the prosthesis, dual-mobility cup implantation was associated with an 8-fold decrease, to 1.6%, in the risk of postoperative instability compared to earlier reports in the literature (1.7% [13] to 24% [14]).

One of the objectives of this study was to determine whether an accurate evaluation of the lesions decreased the risk of intra-operative complications and helped to select the surgical approach, thereby significantly diminishing the operative risk, which is classically very high in this type of procedure [18,19]. We used the original mapping system developed by the SFHG (Fig. 2), which provides assessments of the risk to vessels and nerves and of expected reconstruction difficulties. This preoperative assessment method limited the number of vascular complications, although 2 such events were fatal. Computed tomography-angiography may therefore deserve to be performed routinely when cup protrusion exceeds 15 mm, except if there is a protective bony shell (Fig. 5). When a risk of vascular injury is identified intra-operatively [20], an additional sub-peritoneal approach should be performed to control the vessels, most notably in cases located in one of the four supero-medial rectangles. This strategy differs from the use of an additional approach in the medial iliac fossa between the ilio-psoas muscle and the ilium, as suggested in 1989 by Eftekhar and Nercessian [21], which is designed only for cup removal.

The issue in these patients with often devastating anatomic damage is the assessment of whether outcomes are “satisfactory” or not. Indeed, the wide diversity of the lesions and of the patients’ clinical status makes it difficult to obtain a uniform set of clinical data. Nevertheless, the gains seem significant, with improvements in the PMA score and HHS due chiefly to functional gains, although the absolute values indicate a mediocre clinical outcome (PMA score: 14.2; HHS: 78) that compares unfavourable with the usual results of cup revision [8,9]. Finally, the survival rates after 5 years (88.5%), after 10 years (79.9%), and at the longest evaluable period of 13 years (63.9%) are lower than expected but reflect the severity of the initial damage and the challenges raised by the reconstruction procedure. Consequently, patients should be offered regular and effective follow-up after THA, including clinical evaluations and imaging studies, to prevent the development of severe damage by allowing reconstruction surgery at an early stage of intra-pelvic protrusion. In every case, ensuring long-term stable mechanical stability appeared more effective in improving the outcome than ensuring perfect restoration of the centre of rotation of the hip.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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